The University of California, Davis

THE UCD δ (DELTA*) GROUP IMPROVE-EQUIVALENT INTERNATIONAL AEROSOL SAMPLER (δ-IAS)

Thomas A. Cahill, Kevin D. Perry, and Dabrina D Dutcher
δ-Group, Crocker Nuclear Laboratory, University of California,
One Shields Avenue, Davis, CA 95616
(530) 752-1120; tacahill@ucdavis.edu

DESIGN GOALS:

The δ (DELTA) Group has designed and built a sampler for aerosols smaller than 2.5 μm in diameter ($PM_{2.5}$) that addresses the following goals:

1. Aerosols are collected so as to result in maximum accuracy and precision of data representing both gross and trace species,
2. Aerosols are collected in multiple filters so that standard analytical methods can achieve quantitative mass closure (gravimetric mass = sum of species),
3. Aerosols are collected in accord with standard international protocols in particle size (ambient, $PM_{2.5}$) and sampling duration (24 hr.) to maximize inter-comparability with prior and current global aerosol data.

Desirable factors include a sampler that is small, easily transportable, inexpensive, rugged, able to stand weather, uses little power, easily convertible for different voltages and frequencies.

EXECUTION:

The δ Group international aerosol sampler (δ-IAS) was based upon the California Air and Industrial Hygiene Laboratory's 23 l/min cyclone [1]. This device has become something of a standard 2.5 μm cut point cyclone due to its clean cut point behavior and lack of tails for particles much larger and much smaller than 2.5 μm in diameter. It was adopted by UC Davis for the heart of the 76 site IMPROVE network[2] after side by side tests with many other samplers [3,4]. It was recommended by the UN's WMO Global Atmospheric Watch panel on Quality Assurance of GAW data (1993) and for GAW's Middle Eastern Network (1994-1998) and has been adopted by many other groups [5]. In November, 1996, (Federal Register) the US Environmental Protection Agency deemed IMPROVE the standard for all non-urban US sites. At this point, roughly 300 such cyclones are in active use with another 225 on order for emplacement in the US, Spring, 1999.

---

* Determination of Extinction and Long-range Transport of Aerosols

In the IMPROVE[2] configuration, there are three 2.5 μm channels, each leading to a selected filter medium designed to optimize analysis:

Channel	Denuder	Filter	Analyses
A	none	25 mm Teflon	Mass (gravimetric) PIXE/XRF/PESA[6,7] optical absorption[8]
B	Carbonate	25 mm Nylon	Ion chromatography $SO_4^{=}$, NO_3^-, NO_2^-, Cl^-
C	none	25 mm quartz	Carbon by Combustion OC (4 temps), EC (3 temps)

IMPROVE also has a channel for 10 μm particles.

The key concept adopted by IMPROVE (and the UN) is “integral redundancy”, in which there are enough redundant measurements to establish both the precision and accuracy of the data. Examples include:

1. Air flow is set by a critical orifice, confirmed by a vacuum gauge, and validated by non-critical orifice low pressure measurements (NIST traceable) across the cyclone,
2. Mass (gravimetric) must equal the sum of all species,
3. Sulfur...Iron (by PIXE) equals Sulfur... Iron (by XRF),
4. Sulfate (by IC, Channel B) must equal 3 times sulfur (by XRF/PIXE),
5. Organic Carbon (by carbon combustion) equals organic carbon (derived from hydrogen via PESA),

This protocol has been used by IMPROVE since 1988, resulting in, for example, almost 60,000 of these comparisons. While the vast number agree with extreme precision (r^2 = 0.99+, sulfur versus sulfate), the deviations give new information on chemical states, water bound to aerosols, and other effects associated with certain regions and certain seasons.

In recent years, measurements have shown that the IMPROVE sampler matches many other $PM_{2.5}$ samplers with high precision (errors < 10%) including the widely used virtual impactor[3], the stacked filter unit[4,9] as well as high volume cyclone units previously tested in field inter comparisons [10]. For certain species (sulfates, soil, ...), this has now been extended to physical impactor samples[11] where the shape of the cut point is not critical.

δ GROUP CONFIGURATION, INTERNATIONAL AEROSOL SAMPLER (δ-IAS)

For the δ-IAS, the four standard pots of the IMPROVE sampler, usually used for sequential Wednesday-Saturday sampling, are now used for the Channel A (Teflon), Channel B (Nylon) and Channel C (quartz, tandem) 25 mm filters. A carbonate denuder is used in the inlet to remove nitric acid and other acidic gasses, SO_2, and NO_2. The flow for each is reduced to 7.7 l/min by critical orifices, checked by a vacuum gauge on the pump, and validated by total flow measured by the pressure drop across the cyclone. This results in the same 2.5 μm cut point as IMPROVE and the ability to operate in three times higher mass concentrations than IMPROVE without clogging the filter. The cost is that sensitivity is reduced by a factor of 3.

One great advantage of the δ-IAS configuration over standard IMPROVE is that the total units is only 18 x 30 x 44 cm in size, easily shipped by overnight air carrier. Further, all three channels are supported by a single pump, a 1/3 hp (roughly 250 watt) GAST double piston pump, available in either 110v or 220 v models.

While the δ-IAS mirrors normal IMPROVE operational protocols in many regards, we plan to do addition measurements from the three primary ports to get better sensitivity and additional information especially during extraordinary events and special studies. High priority additional analyses include synchrotron-XRF on Channel A, (better sensitivity than IMPROVE for trace metals), both anions and cations in Channel B (IMPROVE does only anions) and GC/MS speciation on Channel C (IMPROVE does only combustion). The δ-IAS is also flexible enough to allow additional measurements via the fourth port. One such measurement uses a low flow rate (0.1 l/min?) onto a Nuclepore filter. In most circumstances, this allows for microscopic examination of single particles to get shape and morphology.

COSTS:

The units are at present made in the machine shops of the Crocker Nuclear Laboratory, University of California, Davis, at actual cost. The total cost of the system (before shipping to site) is roughly $1250. (including a $350. pump). In addition, there need to be a number of filter cassettes. If the cassettes are loaded and unloaded at the site, and are bought new, the cost for 6 is $120. However, surplus cassettes may be available at nominal cost as IMPROVE is moving to a different system. The samplers normally take about two to three months to order and construct.

REFERENCES:

1. John, W, Wall, S.M., Ondo, J.L., *Atmospheric Environment* 22:1627-1635 (1988).

2. Malm, W.C., Sisler, J.F., Huffman, D., Eldred, R.A. and Cahill, T.A. Spatial and seasonal trends in particle concentration and optical extinction in the United States. *Journal of Geophysical Research,* Vol. 99, No. D1, 1347-1370 (1994).

3. Hering, Susanne V., Bruce R. Appel, W. Cheng, F. Salaymeh, Steven H. Cadle, Patricia A. Mulawa, Thomas A. Cahill, Robert A. Eldred, Marcelle Surovik, Dennis Fitz, James E. Howes, Kenneth T. Knapp, Leonard Stockburger, Barbara J. Turpin, James J. Huntzicker, Xin-Qui Zhang, and Peter H. McMurry. Comparison of sampling methods for carbonaceous aerosols in ambient air. *Aerosol Science and Technology.* 12:200-213 (1990).

4. Cahill, Thomas A., Marcelle Surovik, and Ian Wittmeyer. Visibility and aerosols during the 1986 carbonaceous species methods comparison study. *Aerosol Science and Technology.* 12:149-160 (1990).

5. Cahill, Thomas A. The international fine aerosol networks. *Nuclear Instruments and Methods in Physics Research*. B75, pp. 217-221 (1993).

6. Cahill, Thomas A. Compositional Analysis of Atmospheric Aerosols. *Particle-Induced X-Ray Emission Spectrometry*, Edited by Sven A. E. Johansson, John L. Campbell, and Klas G. Malmqvist. *Chemical Analysis Series,* Vol. 133, pp. 237-311. John Wiley & Sons, Inc.

7. Cahill, Thomas A. and Paul Wakabayashi. Compositional analysis of size-segregated aerosol samples. Chapter in the ACS book *Measurement Challenges in Atmospheric Chemistry*. Leonard Newman, Editor. Chapter 7, pp. 211-228 (1993).

8. Campbell, Dave, Scott Copeland, and Thomas Cahill. Measurement of aerosol absorption coefficient from teflon filters using integrating plate and integrating sphere techniques. *Aerosol Science & Technology*, 22:287-292 (1995).
   *Campbell, David, S. Copeland, and T. Cahill. Comment on "Measurement of Aerosol Absorption Coefficient from Teflon using the Integrating Plate and Integrating Sphere Techniques". *Aerosol Science and Technology* 24:221-224 (1996).
   *Campbell, Dave, and Thomas Cahill. Addendum to Response. *Aerosol Science and Technology* 24:290 (1996).

9. Cahill, Thomas A., Robert A. Eldred, Patrick J. Feeney, Peter J. Beveridge, and L. Kent Wilkinson. The stacked filter unit revisited. In *Visibility and Fine Particles.* C.V. Mathai, Editor. pp. 213-222 (1990).

10. Mathai, C.V., John G. Watson, Jr., C. Fred Rogers, Judith C. Chow, Ivar Tombach, Judith O. Zwicker, Thomas Cahill, Patrick Feeney, Robert Eldred, Marc Pitchford, and Peter K. Mueller. Intercomparison of ambient aerosol samplers used in western visibility and air quality studies. *Environmental Science & Technology*. Vol. 24, No. 7, pp. 1090-1099 (1990).

11. T.A. Cahill, P, Wakabayashi, T. James. Chemical State of Sulfate at Shenandoah National Park During Summer, 1991. *Nuclear Instruments and Methods in Physics Research B: Beam Interactions with Materials and Atoms*, 109/110, 542-547 (1996).